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ABSTRACT

Two trends in the use of quantitative methods of evaluating libraries that have evolved from general systems analysis are discussed in this literature review. The cost effectiveness approach is aimed at discovering new, improved procedures and devices for providing library services; such alternatives make it possible to evaluate how efficiently a library is using resources to provide the services that it does. The cost-benefit analysis approach develops standards and criteria for determining how well the library services provided satisfy the needs and desires of the users and funders of the library. These trends both lead to complex, detailed analysis, requiring sophisticated research techniques. (Author/MBR)

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EVALUATION OF COSTS AND BENEFITS OF LIBRARIES

by

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TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) AND USERS OF THE ERIC SYSTEM."

IR006 528

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February 15, 1978

There is a long history of the application of quantitative analysis to libraries and information centers, back to the days before the term systems analysis was coined, as exemplified in the work of Dewey, Bradford, and Rider. The earlier studies were motivated by a search for new and better methods to solve specific operational problems within a library. e.g. shelving problems (1,2), journal acquisition (3,4), discarding and remote storage of materials (5), book usage patterns (6,7), and circulation control (8). More recently, the emphasis has shifted from operational problems within the library to problems which focus on the relationship of the library with its social environment. Some examples, are determining the size of a library's budget (9,10), the allocation of that budget among different kinds of services (11,12,13), the provision of new kinds of services (14), the justification of large scale automation projects (15), and the possibility of charging users for library services (16). These latter problems are of considerable significance because they bring into question the very existence of the library, they lead to controversy about whether or not one can possibly ever measure in a quantitative way the "value" of a library, and they cause dispute over the kinds of methods that should be used in approaching such problems.

A good discussion of the implications of measuring the value or "goodness" of a library is given by Orr (17). The pressures for doing this, he says, "... are generated by many factors including the success

of these tools in other fields and their adoption by the organizations supporting libraries, the increasingly explicit character of competition for funds at all levels, and the complexity and critical nature of the host of new options being created by technology and by the formalizations of library networks." He finds that librarians are reacting to these pressures in different ways, some arguing that at best it is a necessary evil since the major benefits of a library are essentially intangible and not measureable. Others believe "that it will eventually be possible to measure objectively the goodness of most, if not all, library services ..." In pursuing the implications of such an outcome, Orr distinguishes between two aspects of goodness, quality and value, which correspond to the answers to two kinds of questions: "How good is the service?" and "How much good does it do?"

Orr finds that the most commonly used measures of library quality are those which are related to the number and kinds of resources held by the library, and the most commonly used measures of library value are those associated with the utilization of the resources. He argues that these measures are indirect and inadequate because they rest on unstated assumptions about how well the resources are managed and about the need and demand for the resources. "To summarize," he says, "the principle yardstick needed by the Librarian, aside from measures of costs, would ideally be direct measures of capability, utilization, and value for each of his library's services. The measures of capability,

and utilization would be suitable for checking the predictions of mathematical models relating capability, utilization, and value, and the measure of value would be suitable for aggregation into a global measure of the total value realized from all services." Orr describes this process by the diagram shown in Figure 1. In regard to developing such measures, he notes that thus far only some rather crude measures have been tested operationally.

Orr suggests that the key to developing a direct measure of library quality is to be able to define in an operational way "the universe of needs a service is intended to meet," leading to a behavioral model of library users i.e. a kind of marketing model for libraries. Even more formidable are the problems Orr foresees in developing direct measures of library value. Here he suggests that, rather than take a societal viewpoint, it would normally be more realistic to take an organizational viewpoint in which "value" means value to the organization which is served by the library, as perceived by the managers to whom the library reports. However, he contends, "... few of the organizations that support libraries have defined their objectives sufficiently precisely to make this approach even theoretically possible." This forces the library to look for such indirect measures as savings in user time or users' opinions about the value of service.

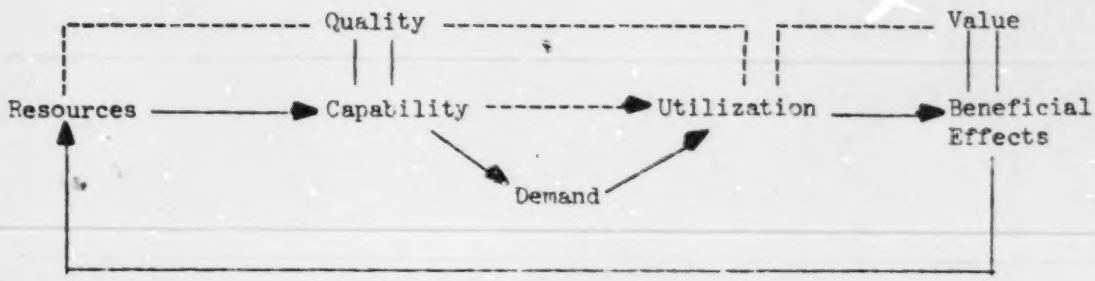


Figure 1. Orr's Diagram of Relations Among Criterion Variables.

Economic Models

Orr's logical analysis leads him directly to difficult economic, psychological, and political problems for which no ready answers are available. The search for a simple, direct measure of user valuation has led some people to advocate direct user charges for library services. Although this seems to be an impractical approach for most libraries, it has caused librarians to give more serious attention to the possibility of using economic models of consumer and producer behavior, as well as macroeconomic models which focus on the general interests of a community. But, the methods for doing this are not well developed. Lesourne (18), in his excellent study of Cost-Benefit Analysis and Economic Theory, cautions that the subject is still in its infancy. "In evidence," he says, "is the fact that a few years ago this book could not have been written." He points out that the subject is not dealt with satisfactorily by existing textbooks on management, economics, or operations research.

Cost-benefit analysis, as Lesourne presents it, starts with a detailed representation of individual behavior including all pertinent restrictions on the individual's possibilities of choice. The analysis then moves on to the formulation of a "social utility function" which is likely to encompass a fairly long, uncertain future and require a careful selection of the mathematical way in which this is to be represented. Furthermore, there can be considerable interplay between the individual behavior and the structure of the social

utility function. Finally, at the third level of analysis is consideration of the production or technical possibilities in making goods and services available. Lesourne notes that with regard to collective and individual public services there is little good economic literature available that gives "due allowance for their genuinely specific characteristics." In working up from the user, through the society, to the supplier, Lesourne leaves a trail of difficult methodological problems to solve.

Lesourne concludes his study with a note of deep discouragement over the obvious limitations of the methodology, the need to introduce so many assumptions about utility functions, prices in markets that don't exist, decision-making objectives, income distribution. "The closer we come to the real situation," he says, "as in the discussion of multiperiod models, or take State activity into account, or introduce future uncertainty, or information cost, or the fact that decisions are imperfect, the more restricted is the area in which the analysis is valid. ... It is easy to make errors in reasoning when the general relations are being adapted to a particular case. ... Inadequate numerical studies are quite commonly carried out with a completely unjustifiable confidence in the precision of the results. In the complex problems associated with urban areas, land use, systems of health or education, accurate analysis requires ample resources, a considerable expenditure of time and very extensive investigations.

When such research cannot be successfully executed, it is preferable to reject immediately the attempt to carry out inadequate analysis to whose results too much weight would necessarily be attributed and which would consume intellectual effort which could better be applied to the assessment of other aspects of the phenomena. In particular, the analysis of the structure, stability, and adaptive capacities of the economic systems under investigation is neglected. In this situation it is adviseable to limit oneself to enumeration of the terms to be included in a complete analysis and to evaluate the orders of magnitude of one or two essential terms. The use of analysis may sometimes lead, therefore, through a sense of false security, to errors almost as dangerous as those arising from apriori judgments. But the subject is in its infancy and gives a great scope for improvement."

Systems Analysis

Cost-effectiveness and cost-benefit analysis evolved from the concern of engineers with the appropriate design of physical systems. A successful engineering design must conform to both the physical laws that govern its operation and the desires of the people who use it. Early in this century, the engineering profession developed methodologies for estimating the social impact of technology. The earliest book on the subject is said to be an 1887 study of The Economic Theory of Railway Location by A. M. Wellington. As early as 1902, Federal legislation required estimates of the benefits and

costs for large construction projects and this requirement was greatly extended by the Flood Control Act of 1936, which established the criterion that "the benefits to whosoever they accrue are in excess of the estimated costs." This phrase has been subjected to many interpretations and the controversy still continues, but it remains a guiding principle in much of cost-benefit analysis. In the 1930's, engineering economy methods were developed to relate systems design with corporate management. This subject became a separate course of study in engineering schools; and eventually a key factor in the industrial management schools founded after World War II.

During World War II many scientists, engineers, and economists became closely involved in military planning. This led to the development of a new expertise called operations research and systems analysis, which greatly expanded the theoretical and mathematical basis for studying the problems of providing and managing technology on a large scale. After the War, this work continued to be done for the military under contract with "Think Tank" companies such as the Rand Corporation. Early in the 1960's systems analysis became an integral part of the basic decision making process of the Department of Defense when Charles Hitch became its comptroller. As head of the Economics Department at Rand, Hitch had been instrumental in developing systems analysis as a way of making recommendations to the DOD on strategic issues. As the DOD comptroller, Hitch sought to integrate strategic planning and financial management by means of

systems analysis. Hitch (19) described these changes as follows. "Traditionally ... military planning and budgeting have been treated as independent activities ... Military plans were prepared without regard to resource limitations and ... were always in far excess of the budgets ... there has always been a tendency to state military requirements in absolute terms without reference to their costs. But the military effectiveness ... of any given weapon system cannct logically be considered in isolation. It must be considered in relation to its cost - and ... to the alternative uses to which the resources can be put ... resource costs and military worth have to be scrutinized together."

Hitch (20) defines systems analysis as "a continuous cycle of defining military objectives, designing alternative systems to achieve these objectives, evaluating these alternatives in terms of their effectiveness and cost, questioning the objectives and other assumptions underlying the analysis, opening new alternatives, and establishing new military objectives, and so on." This process is described in Figure 2. It is important to note the particular importance of the <u>design</u> stage in this process as the driving creative element. Hitch (21) says, "My friend and former colleague, Albert Wohlstetter, used to insist that the systems analyst could contribute much more by inventing new systems than by comparing proposed systems; his own inventions are eloquent testimony to the validity of that view."

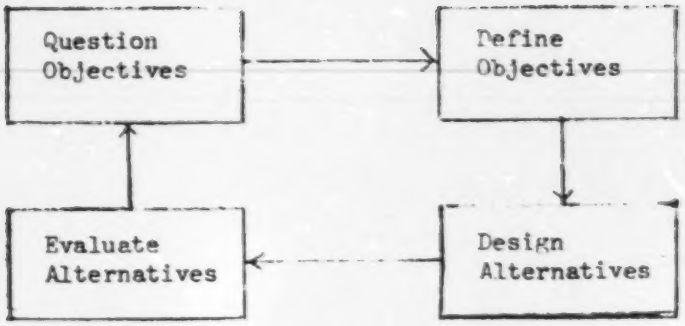


Figure 2. Hitch's Description of Systems Analysis

Program Planning and Budgeting

Systems analysis as a procedure for promoting the design and redesign of systems needs an organizational framework in which to operate. This was done in the Department of Defense by changing the budgeting procedure so that planning was extended from one to five years and appropriations were made on the basis of "programs" or output categories as well as the traditional input categories. The output categories, such as strategic offense, continental defense, research and development, are intended to approximate the major objectives of the DOD. The specification of output categories is made in concrete terms, i.e. the number of bombers, missiles, divisions, ships, etc. which are allocated to them. In this way, approximate but explicit statements of objectives can be linked directly to their costs. The specification of objectives in terms of system outputs is admittedly only an approximate way of defining objectives, but a useful one for systems analysis.

Hitch (20) explained this position as follows: "... it is impossible to define appropriate objectives without knowing a great deal about the feasibility and cost of achieving them. And this knowledge must be derived from analysis. ... Nothing but rigorous, quantitative analysis can tell us whether some objective makes sense or not - whether it is feasible, how much it will cost. Nothing but rigorous analysis can reveal the conflicts between objectives. Nothing

but inventive and ingenious analysis can uncover means or systems that contribute to several objectives, or that function in a wide variety of relevant circumstances, or that satisfy influential people or organizations with quite different views about higher objectives." As to where to begin, Hitch says, "It might appear then that it would make sense to begin with some broad "given" or accepted objective; to derive from them appropriate local or sub-objectives for the systems problem in hand; and then to design the analysis to maximize, in some sense, the proximate objectives. ... Not only is this a plausible approach, it is in some special cases an acceptable one; it is usually (not always) better than making no systems study at all; and it is frequently, given limitations on available time or manpower, the only feasible approach. I think I was the first to use the term "sub-optimization" to describe this style of operations research (in 1952) and I am no implacable or dogmatic foe of its use. ... But in general sub-optimizing is not good enough ..."

Another DOD analyst, Hoffman (22) puts it this way. "If there are 'ultimate objectives' it is not given to most decision-makers to know what they are, nor in most decisions need they know; rather, at each level, the objectives are means to achieve some higher-level objective - 'one man's means is another man's objectives.' The following points emerge ...

1. There is a hierarchy of objectives; each level becomes a means to achieve the next higher level of objectives and must be evaluated in terms of the next higher level of objectives.

2. The higher the level of objectives, the longer the chain of substitution of one means for another in order to achieve our objectives.

3. In designing an analysis it is impossible to accept the statement of objectives as given; rather it is necessary to check both higher and lower levels of objectives to make sure that no important links are ignored. Analysis does not take objectives for granted - by exposing previously unperceived relations among the objectives, it changes them.

4. As a practical matter, however, it is impossible to start with the objective of providing for the national welfare and to work down to design of, for example, an air defense interceptor. It is necessary to break in at some level; the process of doing so has been called "sub-optimization."

Cost-Effectiveness

A DOD document (23) defines cost-benefit analysis as "An analytic approach to solving problems of choice. It requires the definition of objectives, alternative ways of achieving each objective, the identification for each objective of that alternative which yields the required level of benefit at the lowest cost. The same analytical process is often referred to as cost-effectiveness analysis when the benefits or outputs of the alternatives cannot be quantified in dollars." In practice most systems analysis at the design level falls into the latter category. Cost-benefit analysis becomes more important in evaluating proposed designs. To the systems designer, economic

effects are the indirect result of more immediate physical effects. Hence, the specification of system objectives in concrete terms is a necessary condition for design.

The output characteristics of a system are usually multi-dimensional. One analyst, Kazanowski (24), lists 400 different criteria that have been used in various cost-effectiveness studies for the DOD. Kazanowski makes a special point to caution against the use of simple-weighting or ratio functions that will combine several output measures into a single measure of system effectiveness. Quade (25) argues that in the immensely complicated problems of public policy it is often adviseable to use a "scorecard" approach in which all of the significant effects are presented in their appropriate scales and the problem of integration is left to the decision-maker. With multiple inputs and outputs the designer can seek to identify physically "efficient" systems which obtain the same and more of at least one output for the same amount of inputs. But without valuations of the various effects, he is not able to make trade-offs between designs where the same inputs yield more of one output and less of another.

The introduction of a cost function partially solves the problem of trade-offs by establishing a composite measure of some system effects. Quade points out that we think it is easier to measure costs rather than other effects because, essentially, what we customarily do is to

transfer any costs that are difficult to measure in dollars over to the benefit or effectiveness side of the cost-benefit or cost-effectiveness equation. Such costs then become negative benefits and are left for the benefit analysis rather than the cost analysis to evaluate. If there happen to be any benefits readily measured in dollars they are likely to be transferred over to the cost side of the equation as cost savings or credits against cost. If we make such transfers then there can be no doubt that costs are going to turn out to be easier to measure than benefits." Thus, in practice "costs" often become those unfavorable effects which are readily measured in dollars, and effectiveness is everything else.

This essentially arbitrary character of cost measurement is one reason why systems analysts are wary of ratio measures, especially those using dollar measures of cost and dollar measures of benefits. By calling some costs "negative benefits" and transferring them to the numerator one could easily juggle a ratio value. The systems analyst prefers to compare the cost of systems with equivalent effectiveness levels. Cost-effectiveness works well in problems where the objective is to minimize the cost of achieving a set of multi-demensional goals at some specified levels of attainment of these goals. Well-developed mathematical techniques for doing this are available such as those used by Cole (16) in her study of Huston Medical Library, or by McGeehan (10) in a study for the

Defense Documentation Center. Indeed, it is generally true that most of the quantitative studies made in libraries thus far fall into the cost-effectiveness category.

Although cost-effectiveness studies at suboptimal level in an organization may be sufficient for the purpose of promoting innovative system design, it is not fully satisfactory for the needs of the organizations responsible for systems management. Cost-effectiveness and program-budgeting received enthusiastic support from President Johnson after only a few years of experience in the Department of Defense, and he mandated its application throughout the Executive Branch of the Government in 1965. It was a gigantic administrative experiment that floundered badly and all but disappeared after five years. There were numerous factors that contributed to the demise of program budgeting. According to Schick (27), among other causes "PPB failed because it did not penetrate the vital routines of putting together and justifying a budget." Quade (25) says "not enough leadership, support, and resources were invested on the behalf of PPB. Good analysis and data were also in short supply and those available did not always give sufficient consideration to budgetary traditions and institutional loyalties. ... Program budgeting as implemented in the Federal PPB systems, may have had some defects too. PPB seems to be designed for a world of separable goals rather than one of interdependent goals ... It works best, or only, when any given program or means affects one rather than several goals.

Cost-Effectiveness Analysis in Libraries

A recent study by Cole (16) at the University of Texas provides an exceptionally good view of the state-of-the-art in cost effectiveness analysis in libraries. Cole presents six models which describe procedures for satisfying the effectiveness requirements in various important operations. The models make use of a powerful analysis technique called mathematical programming in which a set of equations are developed to specify: (a) how the various activities under consideration relate to each other, e.g. "Do this before doing that. Do either this or that."; (b) how the activities relate to the resources needed in their performance, e.g. labor, space, materials, time, etc.; and (c) any special restrictions and objectives regarding the use of resources, e.g. "No more than 10 people. No less than 1 hour. Minimize waiting time." Two of Cole's models minimize the cost of processing and cataloging library materials. Two models minimize the cost of interlibrary lending and borrowing. The remaining two models determine equitable user fees and an optimal acquisition budget. The latter two models minimize deviations from stated goals in the allocation of funds, rather than minimize cost; i.e. for a fixed cost level, a plan is sought which comes closest to the objectives.

Cole provides useful verbal descriptions of the models which are reproduced in Figures 3, 4, 5, 6, 7 and 8. Each of the specifications is represented by appropriate equations in the mathematical programming model. The simultaneous solution of the equations is the optimal policy to follow. This kind of modeling has considerable appeal to decision-makers since it permits them to describe a system in as complete a manner

VERBAL DESCRIPTION OF COST ALLOCATION MODEL

Recover out-of-pocket costs as closely as possible through the services which actually incur the costs
Recover out-of-pocket costs plus a portion of support costs which is dependent upon usage through the usage based allocations
Recover total operating budget through usage-based allocations plus base fees for each institution
Describe relationship between burden of costs recovered through different services
Describe relationship between burden of costs recovered through different user categories for the same service
Limit ranges of charges for different user categories for the same service
Describe relationship between institutional base fees
Maintain non-negativity of allocational factors

VERBAL DESCRIPTION OF MATERIALS BUDGET ALLOCATION MODEL

Come as Close as Possible to Collection Policy Goals for Current U.S. Publications in All Fields
Come as Close as Possible to Collection Policy Goals for Retrospective and Foreign Publications in All Fields
Retain Required Subscriptions and Standing Orders
Purchase a Certain Ratio of Journals to Monographs in Each Field If Desired
Do Not Violate Any Policy of Maximum or Minimum Number of Purchases in Each Field
Do Not Exceed Current Materials Budget For All Purchases
Do Not Violate Any Established Policy by Spending Above a Certain Amount on Particular Types of Purchases

Figures 3 and 4. Cole's (16) Allocation Models

VERBAL DESCRIPTION OF ACQUISITIONS MODEL

All Requests are Required to be Processed within a Certain Amount of Time

All Material Arriving is Required to be Received and Sent to Cataloguing or Other Destination within a Certain Amount of Time

Labor Requirements are Described

Equipment Requirements are Described

Supply Requirements are Described

Labor and Equipment are Retained throughout All Time Periods

Objective: Minimize Cost of Operations

VERBAL DESCRIPTION OF CATALOGUING MODEL

All Materials are Processed within a Certain Amount of Time from Receipt

Cards for all Materials Processed are Produced within a Certain Amount of Time

Labor Requirements are Described

Some Labor Types can do Tasks Usually Assigned to Other Labor Types

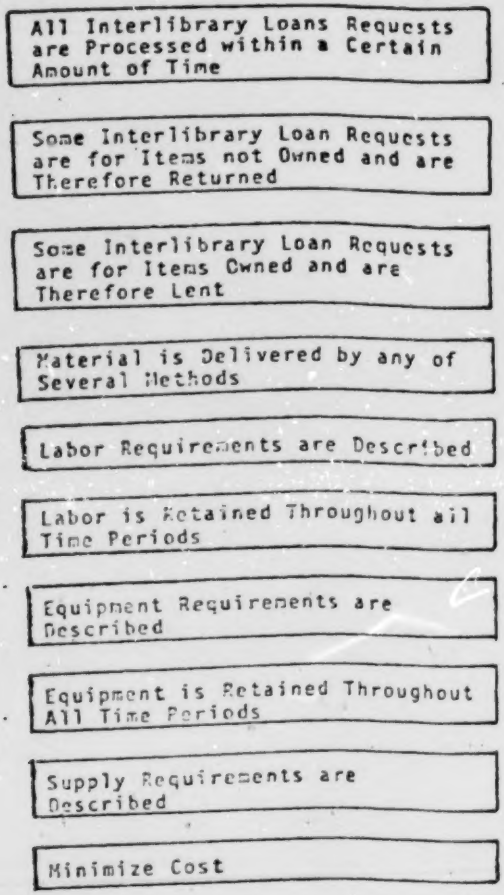
Equipment Requirements are Described

Supply Requirements are Described

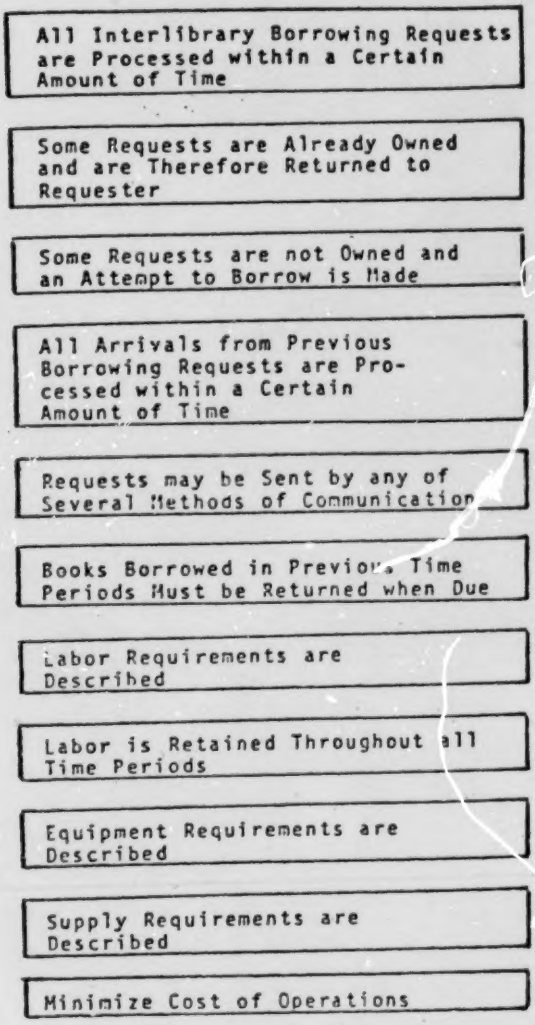
Minimize Cost of Processing

Figures 5 and 6. Cole's (16) Acquisition and Cataloging Models

VERBAL DESCRIPTION OF INTERLIBRARY LENDING MODEL


All Interlibrary Loans Requests are Processed within a Certain Amount of Time
Some Interlibrary Loan Requests are for Items not Owned and are Therefore Returned
Some Interlibrary Loan Requests are for Items Owned and are Therefore Lent
Material is Delivered by any of Several Methods
Labor Requirements are Described
Labor is Retained Throughout all Time Periods
Equipment Requirements are Described
Equipment is Retained Throughout All Time Periods
Supply Requirements are Described
Minimize Cost

VERBAL DESCRIPTION OF INTERLIBRARY BORROWING MODEL


All Interlibrary Borrowing Requests are Processed within a Certain Amount of Time
Some Requests are Already Owned and are Therefore Returned to Requester
Some Requests are not Owned and an Attempt to Borrow is Made
All Arrivals from Previous Borrowing Requests are Processed within a Certain Amount of Time
Requests may be Sent by any of Several Methods of Communication
Books Borrowed in Previous Time Periods Must be Returned when Due
Labor Requirements are Described
Labor is Retained Throughout all Time Periods
Equipment Requirements are Described
Supply Requirements are Described
Minimize Cost of Operations

Figures 7 and 8. Cole's (16) Interlibrary Loan Models

as is needed by simply adding more statements to the model. Such specifications can be modified by changing the values of the parameters in the equations or by changing the form of the equations.

The specification of the effectiveness of a system in a mathematical programming model can include both quantitative and qualitative attributes, although the latter must be translated into logical and numerical equivalents. For example, specification that the acquisitions in a particular subject area must be no less than some minimum amount is a way of maintaining a certain breadth of coverage. Also, specification that all interlibrary loans must be processed with a given time period is a method of establishing a qualitative standard for these activities. In this way, the system effectiveness defined in the model is an approximate statement of the objectives for the system, and the solution to the problem is an approximately optimal policy for satisfying these objectives. When cost minimization is one of the criteria for an effective system, then the model represents a powerful form of cost-effectiveness analysis.

Mathematical programming models help to specify objectives explicitly and completely as a list of effectiveness requirements; but as more activities are included in a single programming formulation, the size and complexity of the requirements list can increase greatly. Hopefully, there are subsets of such large-scale, complex problems which can be solved independently of one another, but where this local autonomy is lacking the analytic problem can be formidable. Even more formidable

can be the problem of translating complicated specifications into mathematical statements that are consistent with the algebraic rules for finding solutions to such problems. Frequently, mathematical programming problems are solved with the aid of computers. This is one of the reasons why such analysis is not always successful as an aid in clarifying top-level decisions. Management and the public may not be prepared to accept arguments which are based on complex logical model, and which require large computers to calculate the effects of changes in system requirements.

An excellent, recent example of the use of mathematical programming to guide top-level library decision-making is a study by McGeehan (10) for the Defense Documentation Center. McGeehan uses a "goal programming" methodology that is similar to the method used by Cole. McGeehan's study is aimed at preparing a long range program budget which will select a group of projects that come as close as possible to achieving a specified list of objectives or goals and priorities in meeting these goals. The computation seeks to satisfy all of the stated goals simultaneously. Where there are conflicts and not all goals can be met, choices are made on the basis of the priorities set by management. The kinds of goals considered by McGeehan are as follows:

1. Maximum and desired total staff, and desired total labor cost.
2. Proportions and absolute amount of staff effort allocated to basic services and development services.
3. Desired staff effort for individual projects.
4. Proportion of staff effort serving different user classes.

5. Absolute levels of effort needed for particular activities.

6. Desired proportion of effort in different projects aimed at (a) providing access to information as opposed to documents, (b) providing access to owned as opposed to remote documents, (c) promoting the use of services, (d) promoting more timely service, (e) conserving resources.

All together McGeehan uses on the order of 50 effectiveness statements. He notes that "The temptation is strong to formulate additional constraints that express interesting relationships among the variables. Indeed, additional constraints would add to the model's sensitivity. ... On balance, a more complex model ... would appear to be counter-productive until such time as those who will operate it ... have mastered the goal programming technique and can actively participate in expanding the basic formulations."

Cost-Benefit Analysis

Among other things, cost-benefit analysis is an attempt to reduce the complexity of a decision problem to only two outcome measures: cost and benefit. Cost is widely used as a comprehensive indicator of an important aspect of an organizations effectiveness. Costs are closely related to expenditures of funds, although consistent rules of interpretation must be developed to show how to account for costs so that they can be related to other effectiveness measures. In business firms costs are subtracted from revenues to yield profit, which when combined with total investment is a useful measure of a firm's successfulness. However, profitability is only one indicator of social value and must be carefully interpreted, often in the light of many other indicators.

In many organizations that don't have revenue measures, it is instinctive to look for an equivalent measure to business profitability as a simple, common gauge of social value, and the term "benefit" is widely used for that purpose. But, the procedures for determining dollar amounts of benefit are not well defined. Cost often means hard dollar outlays, and benefit means "everything else" which raises very difficult questions about how to come up with a single reliable number. Often, benefits include the net effects (including costs) which will occur in the uncertain future, raising questions about how to establish an equivalence between future effects and their present worth, and how to take into account the uncertainty of future events. Another major source of difficulties is how to include the net impact on persons and organizations which are external to the responsible organization. How do you take into account the relative need of those parties for such benefits? How pertinent are such benefits to the responsible agency's decisions?

At present, there seems to be considerable reliance on "consistency" and standardized procedures as a substitute for accuracy. In many decision situations in which changes are considered repeatedly and in only relatively small incremental amounts, consistency can be a reasonably safe "rule of thumb" to follow. However, in making large, one-of-a-kind decisions, consistency has no meaning and the appropriate methods for one such decision may be quite different for another.

Even if we can measure the economic costs and benefits in a

reasonably accurate way, we are still left with the problem of how to combine those two numbers into a single indicator of preference. Many organizations use the old criterion from the 1936 Flood Control Act, namely, that benefits exceed cost. Some want benefits to exceed cost by some designated amount in order to recognize the inherent uncertainty in the benefit measure itself, and also taking account of the fact that a commitment made on one project may cause the organization to forego opportunities to act on other possible future projects. In this way there is a certain hedging of the gamble inherent in any investment project, and also a recognition that different projects aimed at different objectives may yield varying amounts of benefits for the same level of costs. Clearly, if all of the projects attain the basic purpose, the one with the greatest economic benefits is to be preferred, other things being equal; but if we forego greater benefits in one project with one purpose by choosing another project with less benefits at the same cost but with a different purpose in mind, then we imply the existence of some higher priority scheme that allocates expenditures on some basis other than simply the benefit-cost relationship.

Finally, even if we can settle the problem of conflicting objectives in some way and concentrate on cost-benefit relationships alone, what do we do when projects alternatives vary in both cost and benefit. A good example of this is a recent study by the General Motors Research Laboratories (27) of the problem of controlling automobile emissions of toxic fumes. The study estimated the benefits to

society and the costs to the vehicle owners ("and, ultimately, to society") of different levels of emission control ranging from 0% to 100% effectiveness. Representative curves showing the cost and benefit relationships are depicted in Figure 9. In presenting these data the argument is made that "net benefits" or the difference between benefits and costs rises to a maximum value at a control level which is well below the point where total benefit equals total cost. Since the Clean Air Act specifies control levels of 94% or better on the toxic substances studied, it would incur a net benefit deficit of some $30 billion as compared with a positive net benefit of $16 billion for an "optimal" level of control which is substantially below the Clean Air Act requirements. If indeed the analysis is valid and the Act stands, then the decision to do so depends on something other than cost-benefit considerations.

Psychic and Social Aspects of Decisions

One outspoken critic of cost-effectiveness and cost-benefit analysis, Hoos (28), argues that the techniques of systems analysis are not appropriate when we are dealing with problems which are essentially human and social. She finds that methods such as cost-effectiveness and cost-benefit analysis tend to force concentration on the measureable parts of a problem rather than on the problem as a whole. "It is often," she says, "that these elements are relatively less important than those which could not be objectively weighed or meaningfully weighted." Recent

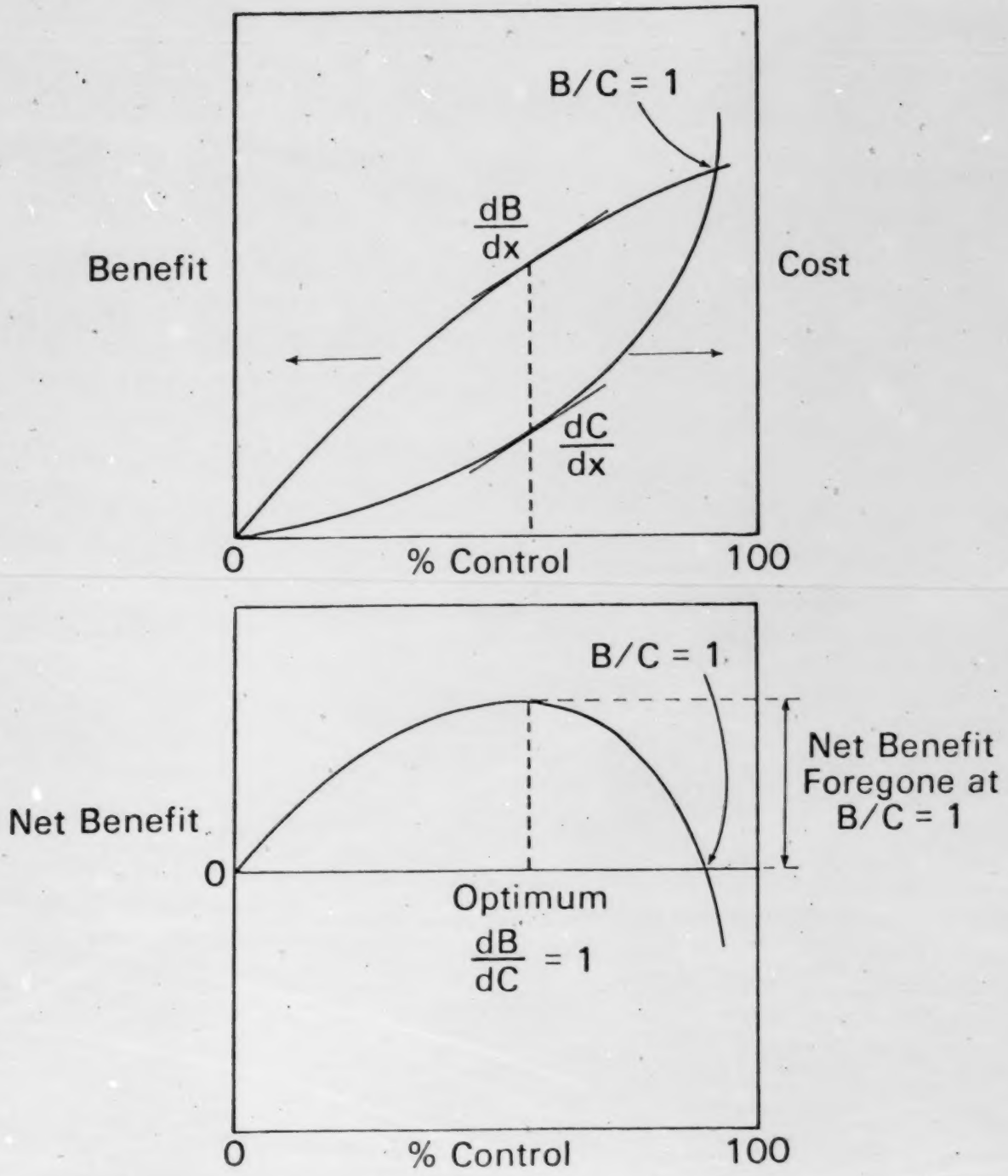


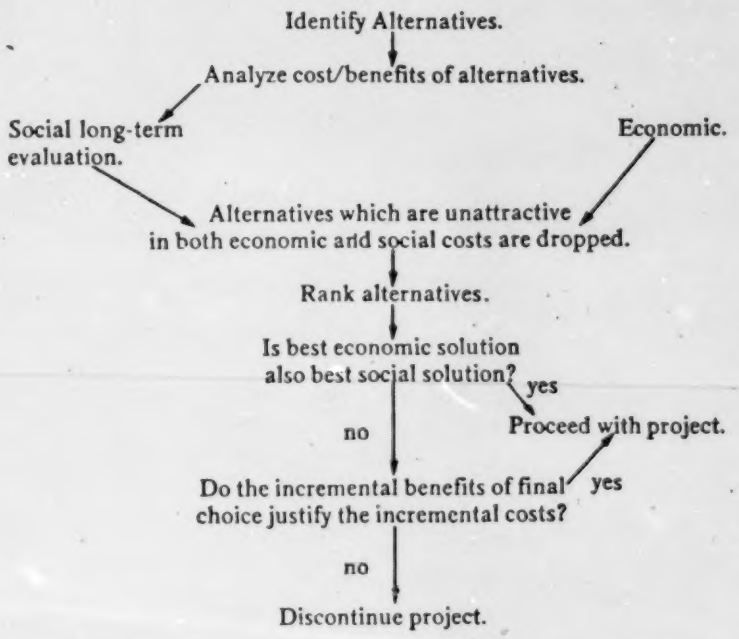
Figure 9. Choice Criterion for Estimating Optimum Control Levels (28)

developments in public policy analysis and technology assessment have tended to give much more attention to the psychic and social effects of operations which affect the public. Often this is done in the context of cost-benefit analysis.

The National Environmental Policy Act requires that assessments done under its auspices consider "environmental amenities and values" along with more easily quantifiable items. A general methodology for preparing environmental impact assessments is shown in Figure 10. It recommends that projects be evaluated on both an economic and a societal basis to screen out unattractive projects on both counts and to try to identify those projects which are highly favorable on both counts. If no such project exists then it is necessary to evaluate the tradeoffs between the two kinds of benefits and costs. In the General Motors emission control study (27), mentioned above, an effort was made to evaluate the psychic benefits of clean air in a manner which is commensurable with economic benefits. The study notes that the most useful single source of data on psychic benefits is surveys of opinions. The precision and usefulness of survey data depends in a major way on the questions asked. "Even small changes or variations in the wording of questions can make the comparisons of results between different surveys and different years very doubtful."

In order to obtain measures of psychic cost in dollar terms, the GM study sought to find out how much people would be willing to pay for reduced air pollution. Willingness-to-pay data must be interpreted

Figure 10. A general methodology for preparing environmental impact assessments, under the National Environmental Policy Act.



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cautiously, since there is no way to verify whether people would really pay what they say. There also are questions about how knowledgeable people are about hypothetical situations, how much they are influenced by suggested answers, and how user attitudes change towards paying for public rather than private goods. The GM study sought additional data from expert opinions and from jury awards which could be in excess of estimated economic injuries. The study concluded that psychic benefits tended to range between 0 and 2 times the economic benefits, where the economic benefits are based on the reduction in health related costs and property damage costs. The study used a 2 to 1 ratio in estimating benefits in order to be on the high side in including any other uncerties ties which the analysis may have failed to include.

The valuation of psychic benefits in monetary terms not only makes it possible to compare dollar costs directly with dollar benefits, but it also implies that the problem under consideration can be optimized independently of other societal problems. The assumption is that somehow a dollar earned or lost in one problem area is equivalent to dollar effects in other problem situations. Furthermore, there is the implication that the dollar effects on individuals can be summed to give a measure of social effect, which assumes that the given distribution of income is equitable and not part of the problem. Finally, the assumption is made that the long-run societal effects can be compared with the short-run effects by making appropriate economic adjustments to future

effects, i.e. discounting them at certain interest rates. These kinds of assumptions are the concerns of economic theorists and of critics like Hoos (28) who argues that "Cost-benefit analysis encourages preoccupation with bits and pieces; suboptimization serves as a useful rationalization for failure or inability to grasp and grapple with large wholes." Her concern with systems analysis is largely in its excessive reliance on techniques at the expense of conceptualization, basic research, and professional judgment.

The increased attention being given to the psychic and social dimensions of decision problems may not have its greatest effect on the refinement or enrichment of the analytic techniques used in cost-benefit analysis but rather in our understanding of how decisions are made and possibly should be made by the people responsible for an activity. There is a mistaken presumption often that the analytic solution to a real problem is also the real solution which should be used. This presumption disregards the fact that the analytic solution is a solution to a theoretical problem that in some way approximates the real problem. The degree to which it approximates the real problem depends on the nature of the real problem as well as the ability of the analysist to represent it in mathematical terms. There is usually a certain amount of fuzziness in this relationship, and consequently the analytic solution has a fuzzy relationship to the solution of a real world problem.

Often the greatest value of analysis to decision-making is in its

ability to convey to a human-decision maker new insights about certain aspects of his situation. These insights may be only indirectly related to the arguments in a particular analysis, but the analysis can contribute in three ways; (a) by helping the decision-maker to become more aware of the nature of the activities he controls, (b) by improving the ability to collect, store, and process relevant information about the activities, and (c) by improving his awareness and confidence about the possibility of predicting the outcomes of the activities. This kind of information is important in helping decision-makers to reach real world solutions which are essentially agreements among humans about how to do things, rather optimal solutions to theoretical problems.

Cost-Benefit Analysis in Libraries

Several attempts have been made to develop an estimate of the value of library service. A rigorous economic analysis was made by Black (29) using the HEW statistics on public libraries for the period 1954-59. Black shows that the data suggests that the circulation of a library depends on the size of the holdings and the size of the staff in such a way that the total cost is directly proportional to the amount of circulation. The ratio of total cost to circulation, or average cost per circulation, is also a good estimate of the cost of increasing circulation by one unit. This cost increases annually at a rate equal to the sum of about one-sixth the rate of increase in book costs and five-sixth the rate of increase in labor cost. By assuming that the demand for circulation is proportional to income and inversely proportional to

the cost of borrowing, Black shows that the total expenditures for library service can be expected to grow at the same rate as personal income. Here, the expenditures for library service represent the economic value of the services.

The identification of the value of library services with expenditures is made also by Hamburg et al. (12) in their study of The Free Library of Philadelphia and other public libraries. Hamburg makes two refinements. He assumes that the benefits exceed costs 12.5 percent, since public expenditures should be expected to realize the same average net rate of return as private funds. He also converts circulation transactions to "exposure hours" by readers, using a factor of 2.2 exposure hours per transaction. Hamburg also adjusts the annual expenditures for depreciable items by multiplying it by 1.09. Black also adjusted for depreciation. In this way, Hamburg computes the value of an exposure hour and shows that it increases from $0.31 for small libraries to $0.57 for large public libraries, with an overall average of $0.42 per exposure hour for 1969-70 data. This is equivalent to an average value of about $0.19 per transaction.

Black's model shows that while total revenues are likely to increase at the same rate as personal income, circulation is likely to increase in the same way less the rate of increase in the cost of borrowing. Thus, by holding down the cost per circulation, the library can increase its circulation growth rate. Black showed that there was evidence that the libraries showed from 1.5 to 2% per year

improvement in efficiency over the period 1954-59, offsetting the rising cost of materials and labor. Baumol (30) makes a point of urging that more attention be given to ways to improve the efficiency of libraries by employing labor and material saving procedures and devices. Hamburg, on the other hand argues that an appropriate objective would be to maximize the exposures obtained from a given budget. Both strategies would tend to reduce the cost per unit of service.

A different approach to the measurement of the value of service is taken by Newhouse and Alexander (13) in their study of the Beverly Hills Library. They address the problem of allocating an acquisition budget among different classes of users on a basis of the implicit valuation by the users for the items. They propose a benefit formula in which the benefit of a book during some period is directly proportional to four factors: the price of the book; the circulation of the book in the time period; an estimate of the fraction of the "ownership" benefits which a "borrower" receives; and a number between 1 and 1/2 which reflects the ratio of two types of users: those who would otherwise buy the book to those who would not. In order to determine the total benefit of the book over all use periods, the benefit in each period is discounted to its equivalent present worth and summed.

Newhouse proposes that the library maximize the sum of these benefit measures over all the classes of books, and at the same time stay within the total budget available, that certain minimum acquisition

requirements are met, and that the number of books acquired is sufficient to satisfy the anticipated usage in future time periods. The effect of this rule is that the library will tend to buy books that are expensive and that circulate frequently. More expensive books tend to have greater benefits to borrowers who would otherwise have to buy the books.

To implement his model, Newhouse computes the benefit-cost ratio for each class of books by dividing the discounted sum of the circulation benefits by the cost of acquiring and processing the book. The rankings are not very sensitive to the particular discount rate used although the absolute value changes. The results show that in the fiction classes mysteries have the highest benefit-cost ratio because of their unusually high circulation rate. In general, fiction items with a high immediate use and a rapid decline in later use show a better benefit-cost ratio when the discount rate is high. Items with a steady long term usage show a better benefit-cost ratio with a lower discount rate. The ratios computed with a 10% discount rate ranged from a low of 0.15 to a high of 2.53. With a 4% discount rate the range was from 0.38 to 4.15. By taking various other factors into account, Newhouse estimates that the ratios could be scaled upward by as much as 50%. He believes that by orienting acquisition policies toward the classes with high B/C ratios, the library could make significant improvements in the benefits provided to the community.

Hu, Booms, and Kaltreider (14) made a benefit-cost study of alternative library delivery systems in which they computed benefit-cost

ratios per volume for bookmobile service and for mail-order lending. The average benefit per book was estimated at $0.29 for a bookmobile and $0.47 for a mail service. These were found by averaging different estimates of benefits which were based on (a) savings in book purchases, (b) savings in rental charges, (c) amount users say they would pay, and (d) savings in user time. The authors note that: "The difference in per-book benefits between the two kinds of users is due mainly to the quantity of books these users could borrow." Benefits per user are developed first and then divided by the circulation per user.

When the benefits are compared to the cost of service, the B/C ratios in both cases are less than one, indicating that the services are not economically justified. Even when an estimate of the social benefit of these services to non-users is included, it is not sufficient to change this discouraging result. (The non-users indicated that they would be willing to pay an annual assessment of about half of what the users would be willing to pay.) The data does indicate that the mail service is economically more attractive, and that the average cost for both kinds of services is likely to decline significantly as the volume of circulation increases. Thus, through the elimination of inefficient operations and the consolidation of small programs, these services might come close to breaking-even. Also, there could be social benefits that have not been includedin these calculations.

Summary

In summary, we see two trends in the use of quantitative methods for evaluating libraries. One trend following the cost-effectiveness approach, is aimed at discovering new and improved procedures and devices for providing library services. Such alternatives make it possible to evaluate how efficient a library is using resources to provide the services that it does. The second trend follows the pattern in cost-benefit analysis of developing standards and criteria for determining how well the library services provided satisfy the needs and desires of the users and the funders of the library. Both of these trends lead to complex and detailed analysis, requiring rather sophisticated research techniques. The ability to simplify the analysis depends in a large way on the nature of the production technology, the needs of the users, and the ways in which funds are obtained.

If we can decompose the technology, the community, and the funding into a large number of independent entities that behave identically, then all we would need is an adding machine to make a proper accounting of cost and benefits. For example, if an operation consisted in loaning a large number of copies of the same book to a large number of similar people who had to have the book and their only alternative was to buy the book, then the benefits are equal to the cost of buying everyone books. This could be compared to the cost of loaning the books to show how much net benefit each person receives as well as how much they receive collectively. If there were no other possible ways for the user to satisfy this need or for the lender to provide copies, then there

is little need for studying this operation further.

Fortunately, we don't live in such a simple, uncomplicated, uninteresting and regimented world. Even if alternative technologies are not readily available, who is to say that better ones could not be invented if one tried. Indeed, unless there are alternatives to compare things with, there is no way to evaluate them. Furthermore, such evaluations must always be made against the next best alternative. If we save money using Method 1 because Method 2 costs more, then the amount we save is a good measure of the benefit of our skill as a decision-maker. However, if there were a perfectly stupid Method 3, it wouldn't be meaningful to use the larger savings between Methods 3 and 1 to indicate that we are an even smarter decision-maker than the difference between 2 and 1 indicates.

This same principle applies to the consumer of library services and to the funder. The value of their actions is revealed by the choices they make in the light of the alternatives available to them. If patrons must use the library or funders must provide the budget, there is no value revealed by their actions. They are functioning as robotic elements in some larger chain of events which ultimately results from somebody's decison to do it or not do it that way. It is in decisions of choice that economic values are revealed.

A complicating characteristic of the real world decision analysis is that things are so different from each other and behave in such strangely complicated ways that it is very difficult to cut out one chunk and treat it as self-contained entity. We talk about a library item,

a library patron or a library "use" as though they are all alike, but in reality we know that each one is a very unique entity with very complex relationships to other entities in the library environment. However, in order to make any progress at all in talking about collections of books or users, we must accept the fiction of typical element which can be aggregated to make the whole. How we aggregate these elements does not have to be done in a simplistic way. It is possible to say that there are so many of type A elements and so many of type B elements; and we could go farther and say that there are type AB elements also. Type A elements might have characteristics X and Y in different proportions than type B elements, etc. As we endeavor to be more precise in describing these collections of entities, we become more complicated in our definitions.

The cost-effectiveness approach engages in such analysis to discover new ways of organizing the productive side of libraries. The discovery process itself is essentially intuitive, creative, and non-automatic. However, discoveries are aided by, and justified by, analytic explanations. Sometimes the analysis gives the misleading impression that the new discovery automatically followed from the clear, cool logic of the analyst. Analysis is a way of documenting the search for new discoveries. It makes it possible for people to work together in a common venture and to exchange ideas about discovery problems through time and space. As with any language there are problems of form and content, of precisions and recall, etc.

In pursuing new discoveries, the analyst tries to identify some chunk of the situation that relates to other chunks in a knowable way. He wants to consider how possible changes in the first chunk will change its relations with the others. In doing this, it is likely that he may have to subdivide the first chunk into sub-chunks to see how they interrelate with each other and what changes are possible. And so begins a seemingly endless chain of taking things apart and producing an even more complicated description of how things work. When it is time to resuface with construction designs the procedure goes in reverse. Starting with basic elements and simple relationships, the designer tries to rearrange them into more useful systems. With luck and patience, something great may come of this

An interesting account of this process is given by the Fremont Rider (2) in describing his obsessive concern with the problems of library growth, when he was Librarian at Weslayan University. He made a series of studies of library storage possibilities and came to the one definite conclusion "than no emendations of present library method alone were going to provide a sufficient solution of our growth problem." With remarkabel anticipation of what we now call systems analysis, Rider explained:

> "And the reason for our failure to integrate what were really facets of one single problem was that we were blinded by the status quo. We insisted on continuing to accept as library axioms, unalterable and unquestionable, certain assumptions which no longer had validity, such dicta, for instance, as: libraries are collections of books; books are stored on shelves; library materials have to be cataloged; catalogs have to be made on cards; books must be arranged by their call number, etc., etc., etc. It is not until we have looked behind and beyond every one of these

> --and many other--supposedly basic axioms of library method, and have seriously questioned their validity as axioms, that we begin to make any real progress."

Rider's efforts led him finally to envision microform technology much along the lines that we see it developing today, forty to fifty years later.

The technological possibilities that Rider sought are available today to a degree that he could not possibly have envisioned, since his efforts precede the invention of the computer. In a large measure, today's problems are due to his efforts and those like him. They show us the possibility of different ways to collect, store, and transfer information which can provide better and, in some cases, totally different kinds of services to users. Typically, these changes may not generate enough savings of current cost or generate them quickly enough to justify the funds needed to make the changes. However, if one could count user benefits that are made possible by the changes, one could build a much stronger case for innovation.

To make the case for additional library funds, the need has to be expressed in terms that can be related to the alternative uses of such funds, uses other than for the library. The simplest approach might be to show the benefits in dollars, and that the dollar return on additional funds would be as good as could be expected in any other use. This is not easy to do unless there is a simple direct market, which adequately shows how users value the services in dollar terms. This valuation must be consistent with the preferences of the funder, also. There are

many cases where public institutions do have market prices for services, such as school tuitions and utility rates, but where this valuation is not an adequate measure of the benefit received. They are not adequate in the sense that they cannot be compared directly with the benefit measures in other parts of the economy. For example, the existence of private school tuitions is a good indicator that public school tuitions are not an adequate measure of the benefits they buy.

It is possible to get at these problems through a benefit-cost analysis that constructs a sound theoretical basis for generating fictitious benefit measures that reflect the correct social valuation of services. But, such analysis is clearly going to require much study and experimentation before it will be accepted at face value. Much of the federally sponsored research in systems analysis today is focused on valuation problems and the methods needed for analyzing them. Such work requires an understanding of the psychology of user behavior and the sociology of funding schemes that is as detailed and complex as our understanding of the technology of services, if not more so. And like the patterns of technical inventions, it is also a moving target that is hard to hit, but must be attempted.

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